A SKETCH OF THE GEOLOGY OF MEXICO.

MEXICO is a country whose geology is very little known even by its nearest neighbors. It nevertheless offers a wide range of interesting problems. Its geology has been much misunderstood and this must be the excuse for presenting here a résumé of a portion of the very interesting report[1] recently published by the Geological Institution of Mexico. Aside from the itineraries with detailed observations, the report includes a synopsis of the geology of Mexico by the Director Sr. Jose G. Aguilera. In the following pages is a very much abridged translation, or abstract of Professor Aguilera's paper. The original is accompanied by a small scale map on which the geology is spread over the areas left blank on the older map of Castillo[2] and the whole forms a notable contribution to the geology of the region as well as being perhaps the best general summary of the present state of our knowledge of the subject.

Geographically Mexico may be considered as consisting of a central tableland sloping to the north and northeast, and inclosed between two ranges of mountains which are separated from the oceans by strips of lowland narrowing to the south. The two mountain ranges unite in the central portion of the country, rising above the lower land in the form of a colossal V, the arms of which continue into the United States as the Rocky Mountains and Sierra Nevada. The united range continues south into Central America with the low tableland of Yucatan, to the east rising thirty to forty meters above the sea.

The central tableland or Mesa de Anáhuac with an area of about 666,000 kilometers and an average altitude of about 1700

[1] Bosquejo geológico de México, Bol. del Inst. Geol. de México, Nums. 4, 5 y 6. 270 pp., 5 pl., map. Mexico, 1897.

[2] Bosquejo de una Carta Geológica de la Republica Mexico formada par disposicion del Secretario de Fomento, 1889.

meters, continues without interruption from the high plains of Texas and New Mexico to the valley of Toluca, which rises against the flanks of the Nevada de Toluca, reaching an altitude of about 2630 meters. This great meseta forms a geographic unit of the first order. Breaks in the bounding mountains afford easy communication with the coastal region and furnish outlets for the drainage. It is a continuation of the Great Basin region and has all the characteristics of that area. To the north it widens and decreases in altitude; to the south it narrows and rises. At its vertex are situated the City of Mexico and the two great volcanoes of the country.

In Archæan time the southern, and a part of the western coast of Mexico, rose above the waters and formed a series of islands or perhaps a single strip of land which, as with the northern portion of the continent, served as a point of initial deposition, and around which has been laid down in successive geologic times the beds which now make up North America. The rocks of this period are numerous and present many variations between different types. In the southern portion of Puebla, in Guerrero and Oaxaca where the greater number of exposures occur, their order of deposition was as follows: (*a*) Porphyritic gneiss similar to augen-gneiss, losing its schistosity below and passing into a species of granite; (*b*) Phyllite gneisses resting upon and grading into the preceding beds; (*c*) Mica schists somewhat abundant, at certain points garnetiferous and comformable with the rock below; (*d*) Phyllites, very argillaceous in their upper portion, but with the clay gradually diminishing toward the base and with concordant structural variation from stratiform to schistose. These beds rest upon chlorite, sericite and amphibole schists, which in turn cover the phyllite gneisses.

Later than the deposition of the argillaceous phyllites and before the end of the Palæozoic, there were numerous eruptions in the following order: (1) Gneissic granite, passing into a porphyritic granite which cuts the mica schists without penetrating the phyllites. These rocks are shown in the northwestern portion of the republic in the City of Caborca, Sonora. (2)

Granite proper, cutting the mica schists and the phyllites and shown at most of the Archæan exposures as well in the northwest as the southern portion of the country. (3) Granulite, cutting all the rocks of the Archæan. (4) Hornblende-granite in frequent dikes and occasional stocks, cutting all the Archæan rocks. (5) Pegmatite, passing into graphic granite and occurring as dikes cutting the gneissic and true granites. There seem to have been two distinct periods of eruption of the pegmatite. The older, seen in Sonora, cuts only the gneissic granites, the mica and the amphibole schists. The later and more common type cuts all the Archæan rocks. (6) Greisen, associated with the granites, forming segregation veins. (7) Diorite dikes, later than the preceding rocks but earlier than the end of the Palæozoic. These are very abundant in the southern portion of Puebla and the northern part of Oxaca and Guerrero.

The Archæan forms considerable areas, and in addition to the points mentioned is found in Zacatecas near Fresnilo, in Guanajuato in the vicinity of the capital, in Sinaloa, near the crest of the Sierra Madre, and near Vera Cruz. The rocks also form the axis of the peninsula of Lower California.

The Palæozoic has few representatives in Mexico. The rocks of this system whose age is definitely fixed belong to the Carboniferous. Although considerable areas have been referred heretofore to the Silurian, and fossils characteristic of this terrane and said to be from Mexico, may be found in collections, we know of no exposures proven to be of that age. In the collection of the Institution is a piece of limestone holding beautiful specimens of *Orthis testudinaria* Dalman, and sent to Professor Castillo from the Cuesta de Santa Teresa near Cachuamilpa in Guerrero. Careful search in the locality by Professor Castillo failed, however, to reveal the source of the specimen. Many geologists have assigned to the Silurian the slates found at Guanajuato, Catorce and Zacatecas. Those at Catorce are Jurassic, and while at the other localities there are beds older than the Jurassic, there is no good reason for assigning to them so great an age as the Silurian. With regard to the Devonian Professor

Aguilera has succeeded no better than in searching for the Silurian. A careful study of localities said to have furnished Devonian fossils has only resulted in showing the presence of certain pre-Jurassic rocks whose age, because of the absence of fossils, and the metamorphism which the rocks have suffered, cannot be definitely fixed.

Carboniferous rocks of undoubted authenticity occur along the Guatemala border directly below the Cretaceous. The rocks are compact ash-gray limestones, containing *Productus semireticulatus*. Large areas of rocks in the central and northern portion of the country, assigned by Frazer, Hall and others to Silurian, Devonian and Carboniferous, are now known to be either Cretaceous or of unknown age.

In the absence of rocks belonging to the first two periods of the Palæozoic, it seems probable that Mexico, which during the Archæan was reduced to a group of islands, or perhaps to a single narrow peninsula stretching from California to Tehuantepec and Chiapas, suffered during the Silurian and Devonian a continuation of the ascendant movement which began at the end of the Huronian. The complete absence of stratigraphic and palæontologic data relative to the first subdivision of the Permo-Carboniferous authorizes the belief that during this time the elevation continued, and makes acceptable the hypothesis that it was during this time that the various islands became united and formed the skeleton of the country.

The Mesozoic is represented in Mexico by beds of the Upper Triassic and Jurassic, as well as the whole of the Cretaceous. The Triassic beds indicate a period of depression. The sediments accumulated in marshes and estuaries along the western coast to a thickness probably of 1000 meters; sediments 600 meters in thickness being now found in Sonora. The deposition was interrupted by minor elevations as is shown by lithological variations and the presence of basal conglomerates. The deposits cover a considerable area and are composed mainly of gray, red and yellow sandstones and gray to black slates. In general the rocks outcrop on the crests of low hills and ridges, being

uncovered and resting upon crystalline schists, granites and similar rocks, or are intercalated between the Huronian rocks and the arenaceous marls and slates of the Upper Jurassic. The latter is especially true south of Acatlán and about Tezoatlán. In some instances the Triassic is covered only by the Cretaceous or the Tertiary.

The position of the rocks along the Gulf of California and in the territory of Puebla and Oaxaca indicates that after their deposition they were subjected to an elevation which, continuing to the present time, has placed them more than a thousand meters above sea level in Puebla and more than two thousand in Oaxaca. In spite of the evidence of the invasion of the sea in the Triassic, the absence of marine sediments makes it impossible to trace the old shore lines, but the same absence indicates that the land then extended notably more to the west than at present and that the deposits then made along the coast have since been buried.

While the deposits of the Triassic were made in marshes and lagoons, some of which perhaps communicated with the sea, those of the Jurassic are in general such as denote continental seas and deep water. Certain of the Jurassic rocks, however, seem to have been deposited in an interior sea of slight depth. At the close of the Triassic the northwestern and southern parts of the country were elevated, draining the marshes. At the same time the southeast sank beneath the Lower, and later the Middle Jurassic seas. At the close of the Middle Jurassic there was a further land movement and the Upper Jurassic sea crept in over large portions of Coahuila and Oaxaca. The Jurassic rocks are conformable with the Cretaceous and are intimately folded with them.

The Cretaceous rocks cover much the greatest portion of Mexican territory. They include three well-marked series of beds, the Lower, Middle, and Upper Cretaceous. These correspond respectively the Lower to the Neocomian, the Middle to the Cenomanian, Turonian and a portion of the Senonian, and the Upper to the Danian, and a part of the Senonian of Europe.

The beds of the lower division are largely shales, clays, marls, and greensands. The middle formation is mainly made up of compact ash-gray limestones frequently magnesian, though not in general constituting true dolomite. The limestones are rich in fossils, though they have been much metamorphosed. The upper member occurs only in the northeastern portion of the country and is represented by fine to medium grained, gray to red and yellow sandstones, alternating with clay shales of gray to black colors.

The advance of the sea begun in the Jurassic, continued until the country was converted into an archipelago at the end of the Middle Cretaceous. There was then a general elevation, carrying all but the northeastern portion of the country along the Rio Grande, above the sea. This elevation was accompanied by folding and mountain-making, continuing into the Upper Cretaceous. It was at this time that the main masses of the Sierra Madre of the east and west coasts were ridged up.

The Upper Cretaceous was laid down by a retreating sea and by the close of the Mesozoic, Mexico had its present general outline. There were, however, certain differences. Although the country then as now formed a great triangle with the apex in Central America, the width of the landmass was much less than at present. The Pacific coast line was farther west and Lower California was not yet separated from the mainland. The Gulf of Mexico had a more irregular coast line and extended to the west and southwest, probably uniting with the Pacific south of Guatemala. Yucatan and Florida were as yet covered by the ocean.

During the Eocene there was a series of vertical oscillations, but the total result was an increase of territory. In the Miocene there was along the east coast an invasion of the sea, though not so as to cover the whole of the Eocene area. At the same time the Pacific advanced inland and the first peninsula of the Republic was cut off, forming Lower California. Toward the close of the Miocene a new movement of elevation in the Atlantic region caused the sea to abandon most of its former dominion, the ele-

vation terminating at the beginning of the Pliocene with the emergence of the peninsula of Yucatan and all of the southern part of the country which at the beginning of the Cenozoic had been buried beneath the waters of the two oceans. Upon the Pacific coast the depression seems to have continued in the Pliocene, so that Lower California was for a time cut off from Upper California by a canal and thus formed an island. On the Atlantic coast the Pliocene included a period of elevation succeeded by one of depression and in turn followed by an elevation, the latter continuing into the Quaternary.

It is not possible to fix absolutely the age of all the Tertiary beds. Those west of Laredo in the Rio Grande valley seem to belong to the Timber Belt beds of the Lower Claiborne of Harris. East of the same place are beds in part Eocene, and in part Miocene, possibly Lafayette. In the peninsula of Lower California, particularly along the Pacific coast, is a series of shallow water deposits resting upon the trachytes, andesites and dacites of the Eocene and containing pebbles of rocks erupted in the Miocene with fossils of Pliocene character. Along the Gulf of Mexico are Tertiary marine sediments made up of incoherent shell conglomerates and compact limestones. In the upper portion these contain fossils which in other parts of the continent are Miocene, mixed with recent and Pliocene forms. In the lower part the Miocene forms dominate.

The Tertiary in Mexico, as in the western portion of the United States, was a period of great eruptive activity. The wide variety of rocks and the large masses extruded are equally astonishing. Syenites, hornblende-diorites, quartz-diorites, diabases, porphyritic andesites, mica-andesites, dacites, and basalts are all present. With the andesites are trachytes, rhyolites and obsidians, and many transition varieties are present throughout the series. The eruptions begun in the Tertiary have continued to the present and have had much to do in shaping the topography of the country. The whole of the eruptive rocks are treated separately by Sr. Ezequiel Ordoñez.

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